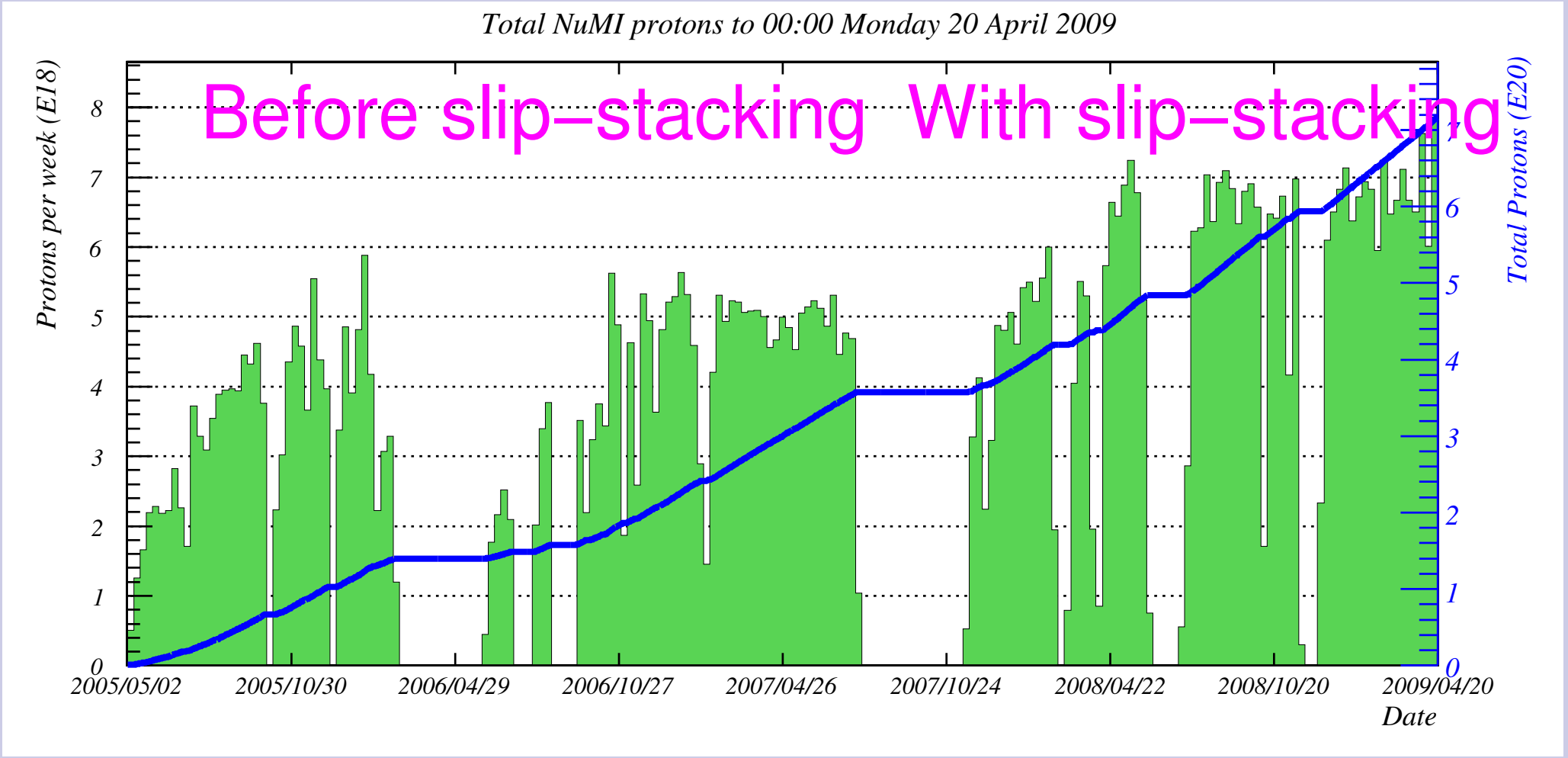
Phil Adamson
Fermilab Accelerator Division

Fuzzing and Main Injector Losses

Monday 20th April 2009

Slip-stacking: more beam!

P. Adamson
Accelerator Division
Fermilab



- Losses now the limiting factor

Slip-stacking: mechanics

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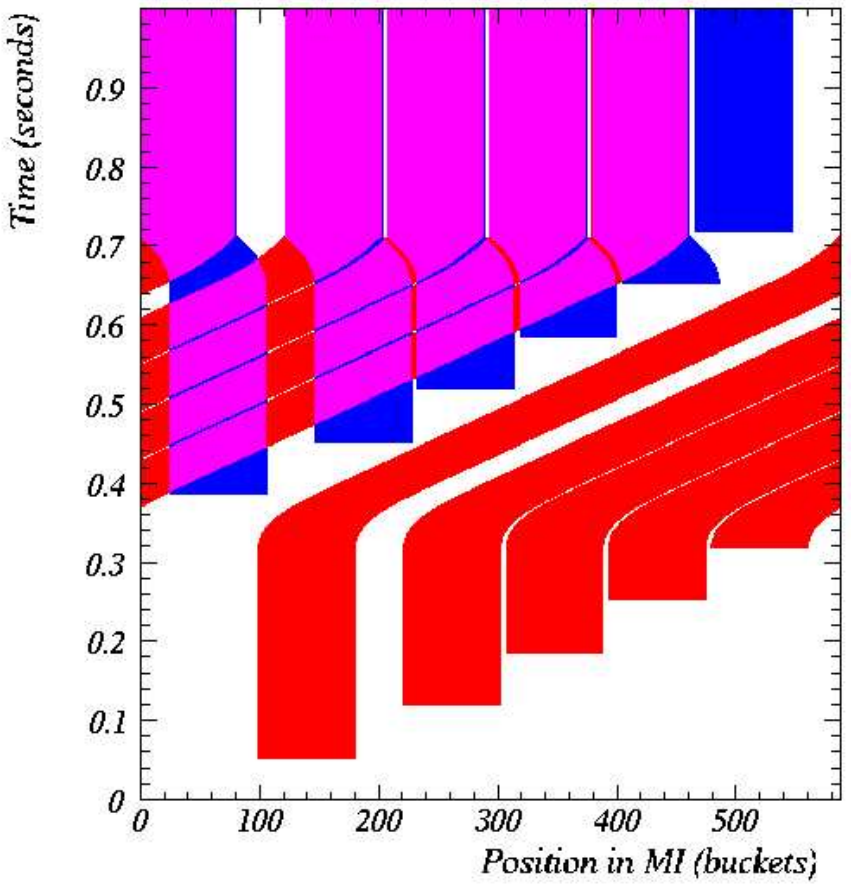

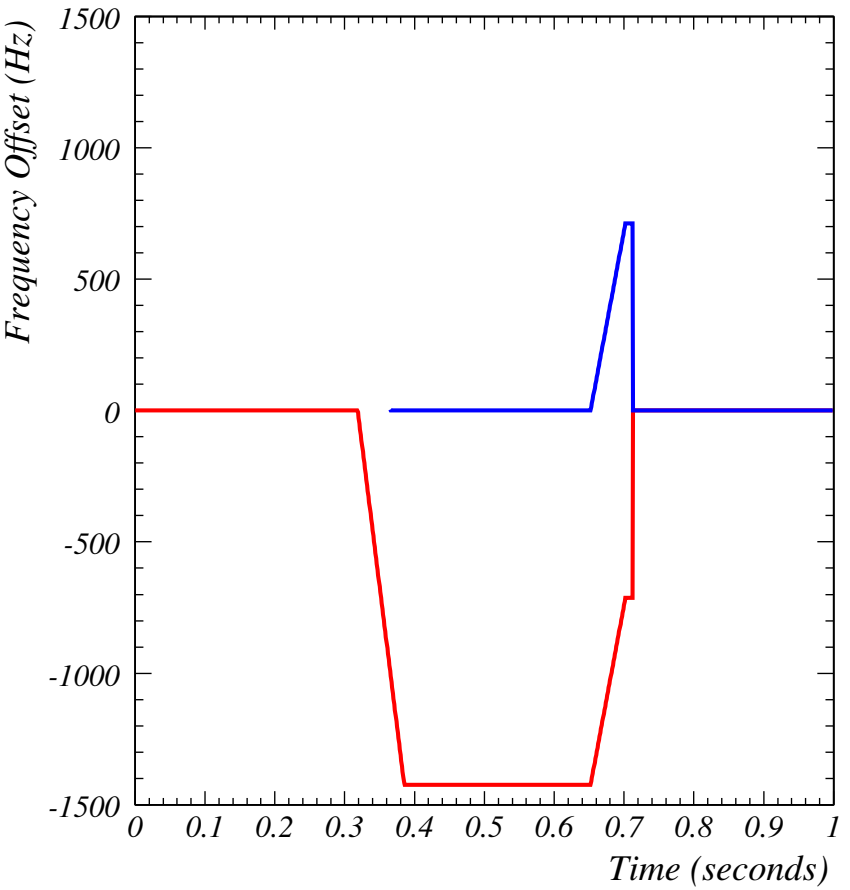

- This pattern is for mixed mode (NuMI and pbar stacking). NuMI-only works the same way.

Small RF buckets

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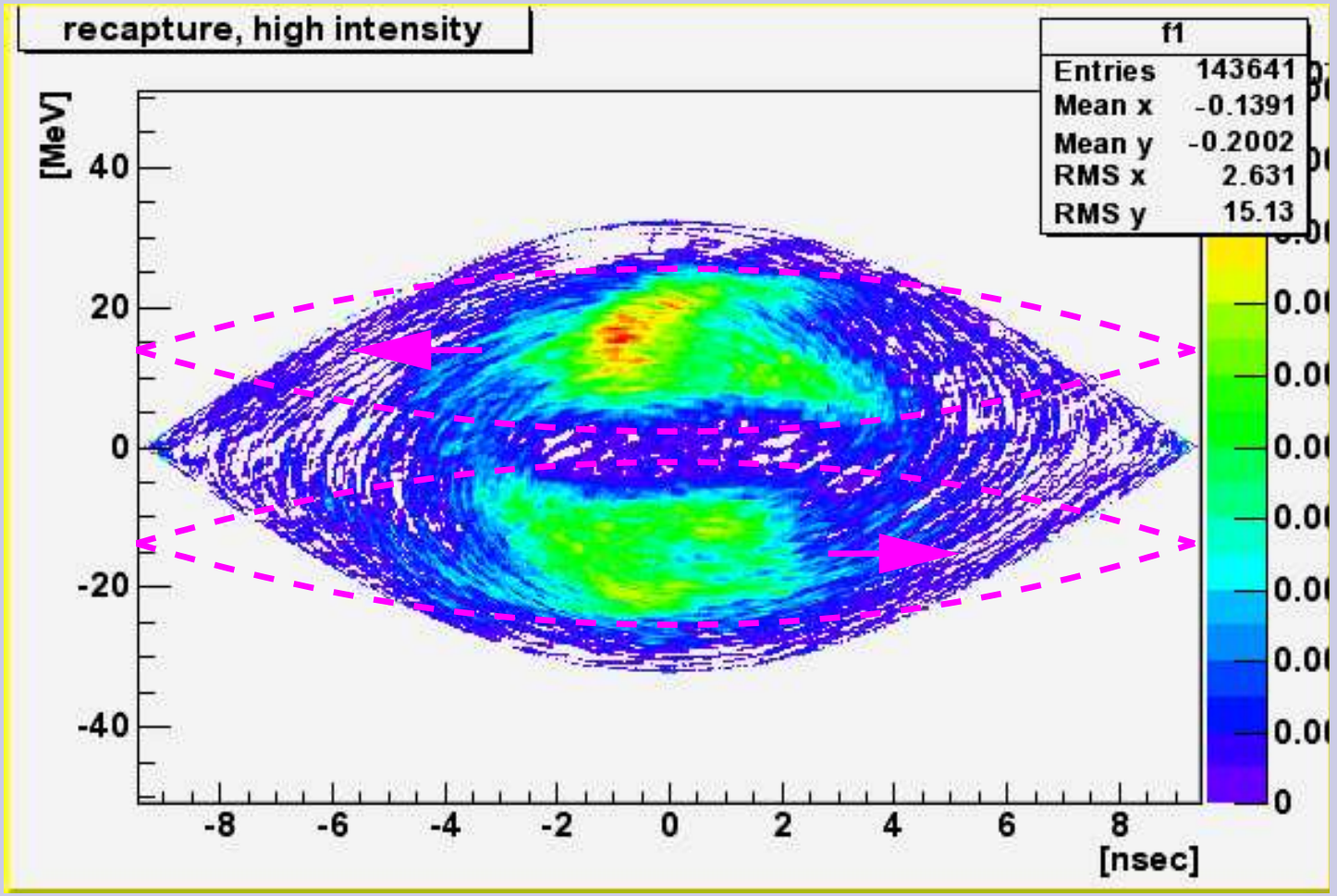

- Tomographic reconstruction of one bunch at slip-stack recapture
- Slipping buckets sketched in magenta
- Injection buckets must be small to allow two to fit in one full 8 GeV bucket
- Not all beam captured at injection → losses

Where do the losses go?

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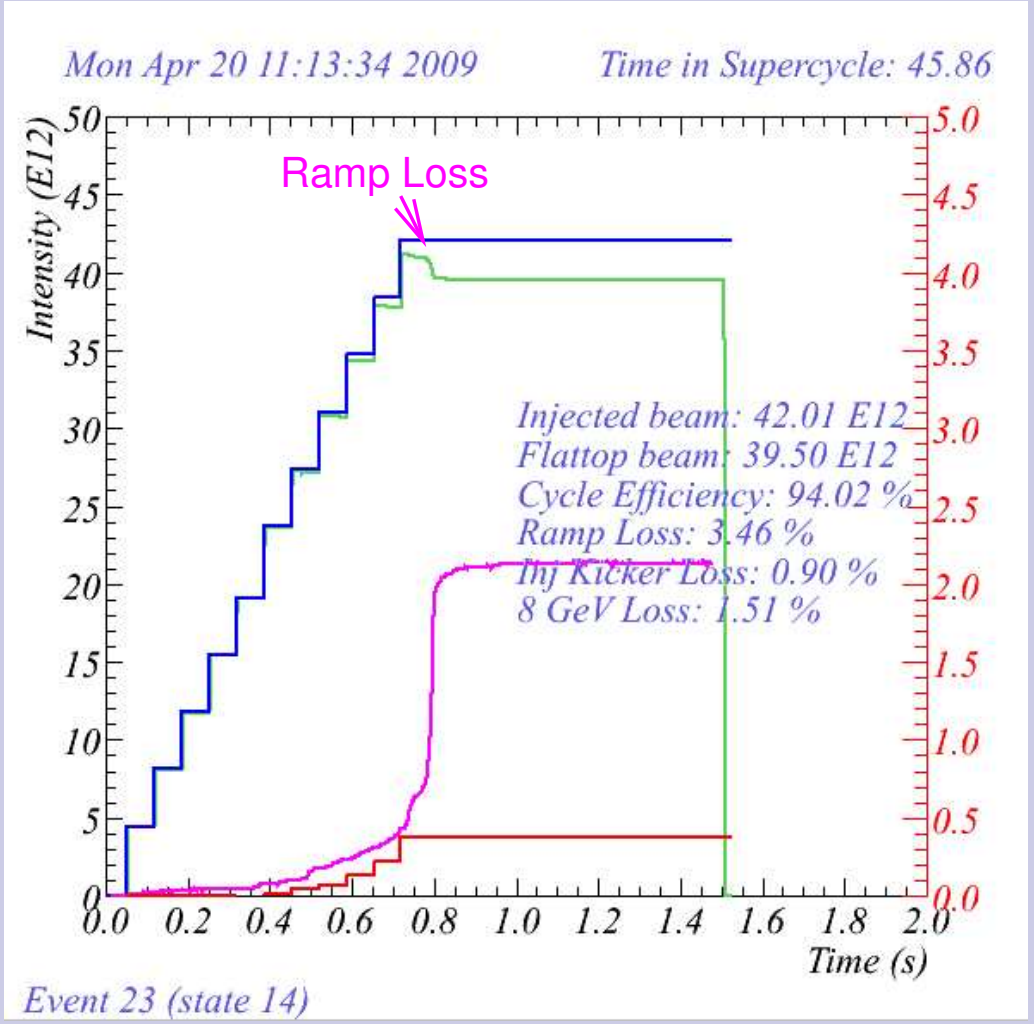
- Dominant losses all originate from beam that was not captured at injection.
- Ramp Loss
  - ⇒ Beam that is never captured in RF buckets is not accelerated, so spirals inward at start of ramp
  - ⇒ MI30 collimators installed to contain this loss
  - ⇒ 95-99% efficient (B. C. Brown, beamdocs, PAC09)
- Injection Loss
- Extraction Loss



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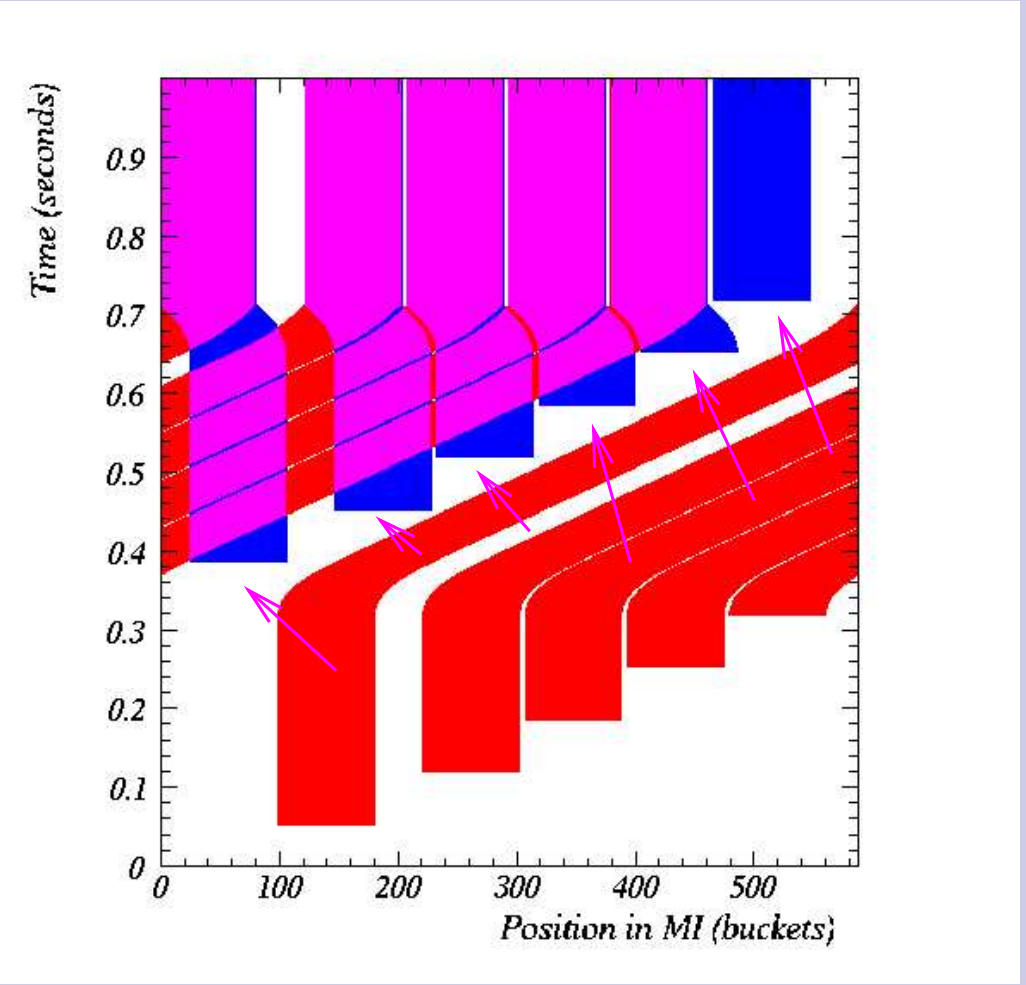
- Dominant losses all originate from beam that was not captured at injection.
- Ramp Loss
- Injection Loss
  - ⇒ Beam that is not captured at injection, or escapes from small buckets gets into injection gap
  - ⇒ Injection kickers fire to inject new beam, but deposit any existing beam in 104-105 region
  - ⇒ Where NOνA penetrations will be installed this shutdown
  - ⇒ Fix is the gap-clearing kicker (fire single-batch kickers a half-turn before injection, so send any beam in the gap to the abort)
  - ⇒ Penetrations at MI40 this summer, then MI39 building...



Where do the losses go?

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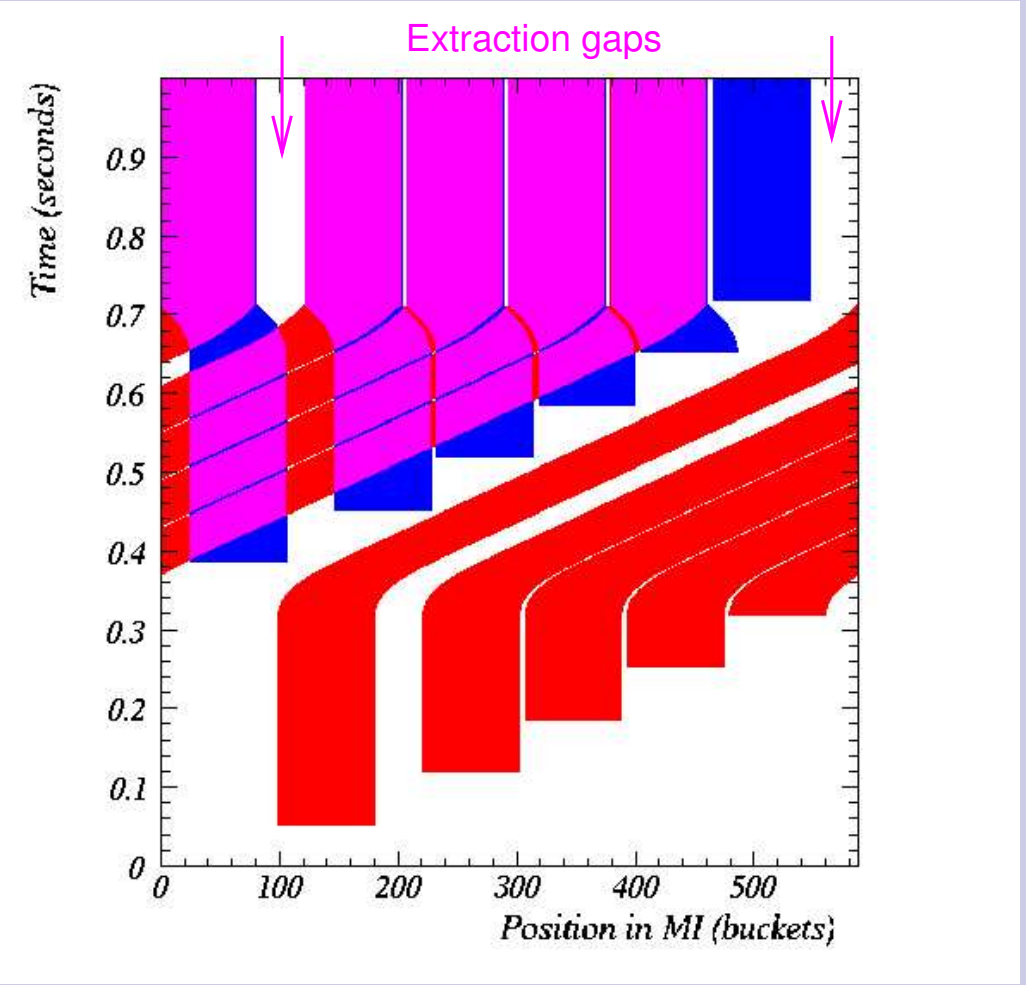
- Dominant losses all originate from beam that was not captured at injection.
- Ramp Loss
- Injection Loss
- Extraction Loss
  - ⇒ Uncaptured beam migrates around circumference, and is captured at recapture time
  - ⇒ Some beam is captured in the extraction gaps, accelerated to 120 GeV, and then smeared over the extraction region by the rising and falling edges of the extraction kicker
  - ⇒ 522 region (extraction to pbar production target) is most radioactive region in the MI tunnel
  - ⇒ Mitigate with fuzzing at 8 GeV



Fuzzing

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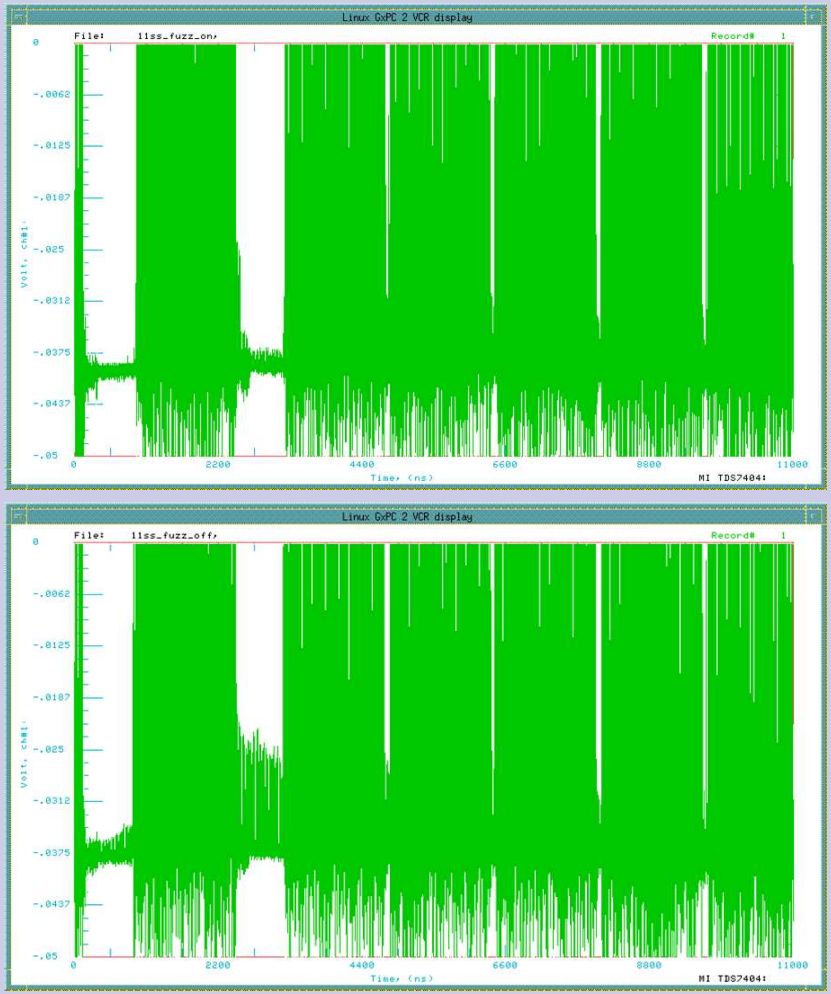
- Kick beam out of machine transversely
- Drive transverse kicker at machine tune (beam signals too small for active feedback to work)
- Chromaticity makes this harder
- Have configured existing damper system to fuzz.
  - ⇒ Works, but power limited. Reduces extraction loss by an order of magnitude.
- Need a new system
  - ⇒ Using an existing kicker is good (speed, tunnel time, cost, ...)
  - ⇒ "spare" injection kicker was installed a couple of years ago
    - For NOνA tail-bumper kicker studies, but not used operationally

MI wall current monitor at extraction:



- Fuzzing on (top) and off with existing damper system

New Fuzzer

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- Damper uses expensive RF amplifiers, which are needed for damping, but not for a fuzzer
  - ⇒ We don't care about the quality of the kick we give to beam that we don't want to keep
- Need to kick about 34 bunches in the extraction gaps
- Send beam to the collimators (vertical aperture restriction)
- Kick needs to be big enough to extinguish beam before acceleration, but small enough that beam doesn't scrape before reaching collimator
- A kick that produces about a 1mm displacement is about right
- 1D kicker
- HV supply and FET pulser
  - ⇒ FET pulser adapted from one that had been built for 750 keV chopper study
  - ⇒ Bought 1kV HV supply to charge capacitors
- Control via a custom-programmed FPGA in NIM module
  - ⇒ Hardware is spare Ashmanskas/Hansen design
  - ⇒ Similar modules used for MI SBD trigger, AP2 BPMs, ...
  - ⇒ Decodes TCLK, MDAT, BSYNC
  - ⇒ Ethernet for communication
  - ⇒ Pulsing pattern configurable via ACNET for each MI state

Results from prototype

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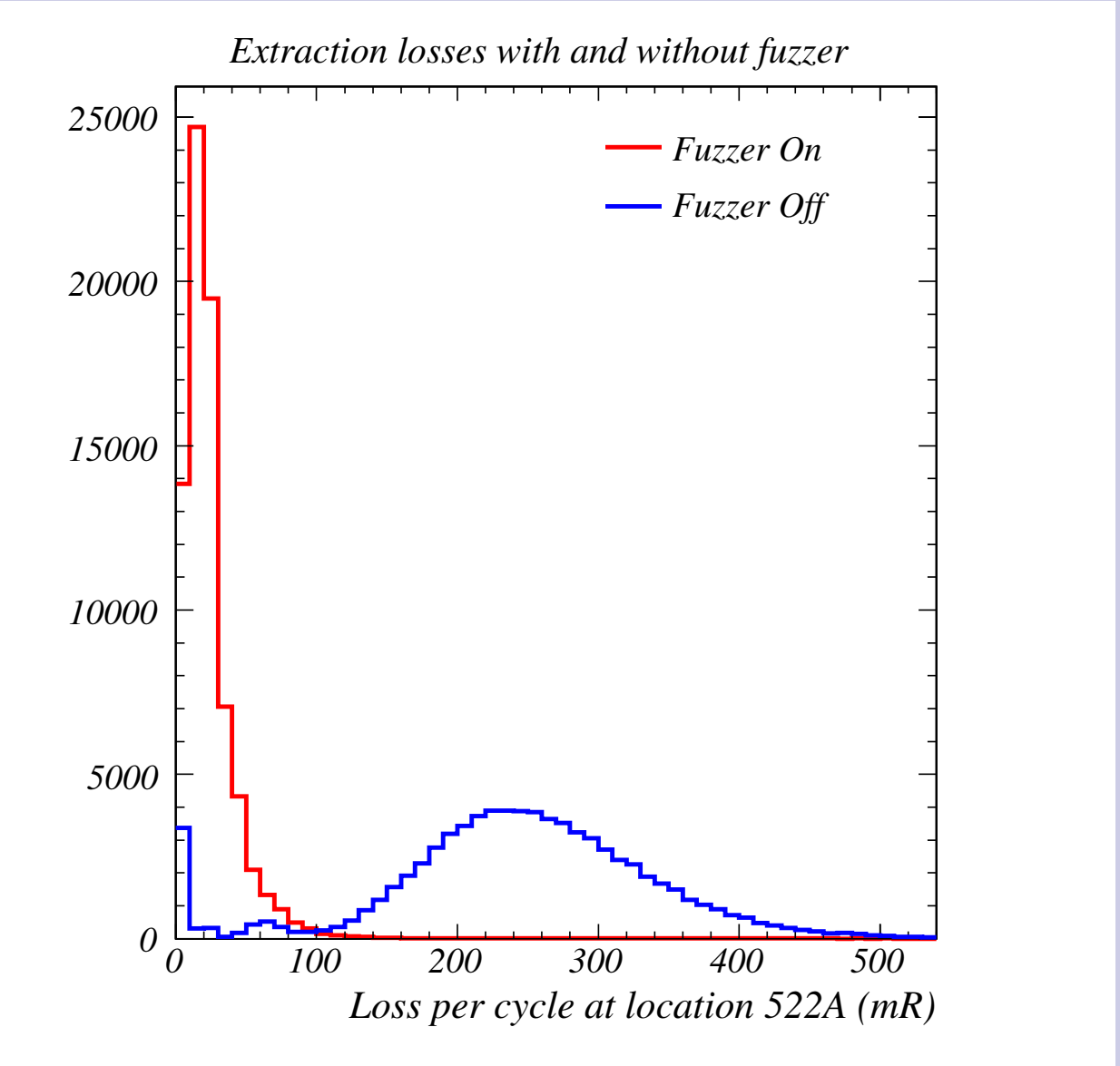
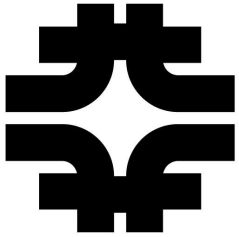
- Prototype uses final control board, HV supply and prototype FET pulser
- (HV/pulser has no ACNET controls, no interlocks, doesn't fit in a rack, ...)
- Order of magnitude reduction in losses at extraction location
- Remainder of loss is scraping at 8 GeV





Summary

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- We have a way to control all 3 major loss mechanisms in the Main Injector
- The prototype fuzzer system has demonstrated the ability to eliminate the extraction loss caused by the slip-stacking process
- The operational pulser (with controls, interlocks etc.) will be ready in the next couple of weeks
- System will be installed and operational in time to reduce losses at 522 for the shutdown
- Thanks to:
  - ⇒ W. Ashmanskas, S. Hansen, T. Kiper, D. Nicklaus
  - ⇒ C. Jensen, G. Saewert, AD EE support techs

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